INVESTIGATION 8-A

Millikan's Oil-Drop Experiment

TARGET SKILLS
- Performing and recording
- Analyzing and interpreting

In this investigation, you will demonstrate that electric charge exists as a quantized entity, using apparatus that allows you to apply a potential difference across parallel plates as you observe the movement of latex spheres.

Problem

Does charge exist in fundamental units and can you find evidence of differently charged objects?

Equipment

- Millikan apparatus for use with latex spheres
- supply of latex spheres
- stopwatch

CAUTION Be careful not to touch open terminals that are connected to a high potential difference.

Procedure

1. Follow the manufacturer's instructions to adjust and focus the light source and also to connect the plates to the source of potential difference. Your aim is to make repeated measurements of the velocity of a sphere under the action of gravity alone (v_0, down) and also under the action of both the gravitational force and the electric force (v_1, up).
2. Examine the position and function of the voltage switch. In the *off* position no electric field will be applied and the sphere will fall under the action of the force of gravity alone. In the *on* position a potential difference will be applied across the plates, with the top plate being positive, and the sphere will rise as the electric force is greater than the force of gravity.
3. Place the switch in the *off* position and squeeze some latex spheres into the region between the plates. (You may need to practise observing the spheres before you actually start timing them. They will appear as tiny illuminated dots.) Follow the manufacturer's instructions for determining direction. The telescope usually inverts the field of view, so the force of gravity is then "up," although some manufacturers have included an extra lens to compensate.
4. Using the voltage switch, clear the field of fast-moving dots. They carry a large charge and are hard to measure. Choose one of the slowly falling spheres and measure its time of travel as it falls, under the action of the force of gravity. Observe the motion for several grid marks in the field of view. (Remember it might be falling "up" in your apparatus.) Without losing the sphere, change the switch so that the sphere rises under the action of the electric field and again measure the time of travel over the grid marks. Before the sphere disappears from the field of view, place the switch in the *off* position and again measure the time of travel over the grid marks. You will need a laboratory partner to record the results so that you can keep your eye on the selected sphere.
5. Repeat your observations for a different sphere from a new batch, and continue making observations for at least 20 different spheres. (Alternate with your lab partner to allow your eyes to rest!)

Analyze and Conclude

1. Calculate the velocity of the spheres for every trial, using an arbitrary unit for distance. For example, if one sphere moved 8.0 gridlines in 3.1 seconds, record its velocity as

$$v = \frac{\Delta d}{\Delta t} = \frac{8.0 \text{ grid lines}}{3.1 \text{ s}} = 2.6 \frac{\text{grid lines}}{\text{s}}.$$

2. Record the velocity of the sphere in two different ways: v_0 to represent the velocity of the sphere under the force of gravity alone, and v_1 to represent the velocity when

the electric force up is greater than the gravitational force on the sphere. Record your data in a table similar to the one below.

Sphere	v_0	v_1	$v_0 + v_1$

3. Complete the calculations for each column in the table.

4. Since the value of $v_0 + v_1$ represents the strength of the electric force alone, acting on the sphere, it can also be considered to represent the electric charges on the sphere. Draw a bar graph with the quantity $v_0 + v_1$ on the vertical axis and "Trial number" evenly distributed on the horizontal axis.

5. Does your bar graph offer any evidence that electric charge exists as an integral multiple of a fundamental charge? Are you able to state the number of fundamental charges that are excess or deficit on your spheres? Explain your reasoning.

8.1 Section Review

1. K/U
   (a) Draw the electric field pattern for a +4 μC charge and a –4 μC charge separated by 4.0 cm. Include four equipotential lines.
   (b) Repeat part (a) for a –16 μC and a –4 μC charge.

2. I If you have access to the Internet, use the sites listed in your Electronic Learning Partner to verify your answers.

3. K/U
   (a) List four properties of electric field lines.
   (b) List two properties of equipotential surfaces.

4. MC Research and report on the use of electric fields in technology and medicine (for example, laser printers, electrocardiograms).

5. C With your classmates, prepare a dramatic skit to simulate Millikan and his colleagues preparing and performing his oil-drop experiment.

6. K/U A pair of parallel plates is placed 2.4 cm apart and a potential difference of 800.0 V is connected across them.
   (a) What is the electric field intensity at the midpoint between the plates?
   (b) What is the electric potential difference at that point?
   (c) What is the electric field intensity at a point 1.0 cm from the positive plate?
   (d) What is the electric potential difference at that point?

7. I A pair of horizontal metal plates are situated in a vacuum and separated by a distance of 1.8 cm. What potential difference would need to be connected across the plates in order to hold a single electron suspended at rest between them?